WEST BENGAL SECRETARIAT LIBRARY

Pamphlets to re-issued by the
Timber Development Section SL NO. 2
(Forest Research Institute Dehradun, U.P India)

Sub: forest / Pamphlets X

123-1

HEAD
Register Entry No 1512
10 NOV. 1938
Received from Forest Ex Dept

FOREWORD.

This little booklet is one of a series of popular publications which are being issued from time to time by the Timber Development Section of the Forest Research Institute at Dehra Dun. A list of other booklets issued or to be issued is given at the end of this publication.

In the past, steel and concrete have been looked upon as the chief structural materials of the engineer. This has been due to the fact that these two materials have been widely advertised and strongly assisted by powerful organisations, whereas wood being nobody's child has gone by default.

Recently in some advanced countries there has been a distinct change in favour of wood, and engineers are discovering that far from being only an unimportant auxiliary, wood is the most economical and practical material for many modern structural purposes.

There are two reasons for this change. The first is that wood can now be made durable for a very long period, and the second is that new ideas in timber joints and wood structures have been evolved which place wood on a very different footing to that of twenty years ago. If the question of primary and recurring costs are considered, increased use of wood as a structural material is also justified.

In conclusion, it is a well known axiom that there is a right place and a wrong place for everything, and it is not the intention that wood should be looked upon as the favoured and pampered child of wealthy parents. All we ask is that it should be given a fair hearing and that engineers "honestly and without prejudice" should consider the ideas presented in these booklets, use their own special qualifications to check them up and give treated timber the same consideration as they give to other structural materials. The Forest Research Institute will welcome their help and co-operation for it holds that timber can stand on its own merits and in not a few cases will be found still standing when other materials have fallen.

H. TROTTER,
Forest Economist,
Forest Research Institute.

DEHRA DUN;
June, 1936.

X
123-1 (298)

RELATIVE ECONOMY OF WOOD, STEEL AND CONCRETE STRUCTURES

BY

S. KAMESAM, M.I.E. (IND.),

Officer-in-Charge, Timber Development and Wood Preservation Sections, Forest Research Institute, Dehra Dun.

The present practice of quoting the cost of steel in terms of weight (per cwt., etc.) and that of timber and concrete in terms of volume (per cu. ft., etc.) is very misleading as regards their relative strength values per unit of money. When an engineer is faced with the selection of material for a certain structure, he looks first for a material that is durable, and available in sufficient quantities, and finally decides which of these materials costs the least amount *for a unit of safe strength* (usually as a beam or a column) and not for a unit of volume or weight.

In general, for the same weight and for the same form of cross-section, irrespective of the species, wood is stronger (assuming a suitable factor of safety) than steel when considered as a beam or as a column. For example, consider an air-dry sal wood joist 2" × 4" and a mild steel rectangular rod ·7" × 1·4", the depth being in each case twice the width. Assuming, however, a safe modulus of rupture of 16,000 lbs. per sq. in. for mild steel and 3,500 lbs. per sq. in. for sal, the above sal joist is about FIVE TIMES as strong as the corresponding rectangular steel rod of the same weight. If the much more economical I section is assumed for mild steel and an ordinary rectangular section for wood, for the same weight, wood has at least the same safe strength as steel. For example, a steel I girder 9" × 4" (weighing 21 lbs. per foot and with a section modulus of 18·02 inches^3) can carry a safe uniformly distributed load of 6·4 tons over a 14 ft. span. An air-dry sal beam 4" × 12", weighing about 15 per cent. less and of the same strength, can safely be substituted for the same I girder. The steel girder would cost Rs. 19 to Rs. 22 whereas the sal beam would cost Rs. 10 to Rs. 12. A sal pole in the round (of 10" diameter at small end and 12" at butt end) having the same strength and stiffness as the above sal beam would cost only Rs. 5 to Rs. 6.

Present day practice in the U. S. A. shows very clearly that for a minimum width of a beam of 2", even for a clear span of

16 ft., a depth of 12″ can be employed with a bridging of 1″ × 4″ at mid-span. The cost of such bridging is inconsiderable. A chir pine (*Pinus longifolia*) floor joist 2″ × 12″ can carry a uniformly distributed load of 3,800 lbs. over a 17 ft. span. This joist corresponds to a I girder 5″ × 3″ and weighing 11 lbs. per foot. The air-dry pine joist (2″ × 12″) weighs only 6 lbs. to 6½ lbs. per foot. If an allowance is made for the bridging at mid-span, the weight per foot is still less than 7½ lbs. per foot.

For the same weight, in compression, wood (practically irrespective of the species) is four to five times as strong (assuming a factor of safety of 4 for wood) as concrete with a working stress of 600 lbs. per sq. in., so that the dead weight of concrete on the foundations is four to five times as much as with wood or steel for the same strength. In addition, weight for weight, reinforced concrete on the average costs about 50 per cent. to 60 per cent. as much as wood, so that for equal strength, wood costs in some cases only a third as much as concrete. In the majority of cases, the cost varies between a half and a third.

If it is possible to use treated timber wholly or mostly in the round, ordinary structures would cost only a fourth to a sixth of the cost of a similar structure of steel or concrete built for the same loads. If an I section (connoting the optimum distribution of material) is used with steel to obtain the maximum strength with a certain weight of material, a round section should be used with wood to obtain the least expensive form of structural timber consistent with strength, besides securing the most efficient and economical conditions for the maximum possible durability with preservative treatment. The extent to which timber in the round can be used depends of course on the nature of the structure. Round timber may not be always very artistic to look at, and this consideration may restrict its use to some extent unless it is covered with planking to give the desired architectural effect. In addition, if it is imperative to employ sizes larger than say 12″ × 6″ × 20′, unframed timber in the square becomes expensive. But this applies with equal force to steel, of which sizes larger than those ordinarily available in the market are difficult to procure, and if specially obtained, their cost goes up considerably. In such cases a truss construction should be adopted. However, in the case of structures for ordinary conditions usually encountered in practice, it is not necessary to use a larger size than 6″ × 12″ × 16′ for wood, and it is interesting to note that this is the present size of some of the crossing sleepers which are now readily available in the market.

If longer lengths are required, timber in the round can be employed, if necessary as a reversed king or queen post truss. With the latter, using a convenient design, the strength of the pole can be almost trebled, whereas for the same safe strength a steel structure will cost very much more. Trussed poles can be used for spans as large as even 40 ft. In some cases, it will be possible, and still consistent with economy, to encase the round timber with a plank facing, as is sometimes done with steel I sections in ocean steamers and buildings. Timber trusses can be designed economically for a span of even 200 ft. but this aspect will not be dealt with here.

Employing a single untrussed wood beam of rectangular section with a maximum size of cross-section of 6″ × 12″ (a size that can be obtained without much difficulty), the maximum moment of safe resistance, *i.e.*, the safe modulus of rupture × the modulus of section, varies between a fifth and two-thirds of a million inch-lbs., depending on the timber. With air-dry sal wood, over half a million inch-lbs. can be obtained. This corresponds to a modulus of section of steel I girders of 10″ × 5″ weighing 35 lbs. per foot. The weight per foot run of air-dry sal for this modulus of section is only about 28 lbs. In the U. S. A., the usual size of railway bridge stringers is 6″ × 16″, using pine or Douglas fir, which have a modulus of rupture in static bending of about 8,000 lbs. per sq. in. This corresponds to a moment of safe resistance of about half a million inch-lbs. As the modulus of rupture for green sal wood is about 14,000 lbs. per sq. in., sal bridge stringers, 6″ × 12″, will resist about the same load. With air-dry sal, 50 per cent. more strength can be expected. Generally speaking, unless the space available is limited, practically any required safe modulus of section can be obtained by using the requisite number of 6″ × 12″ stringers placed side by side. In the U. S. A. a moment of 2·7 million inch-pounds is obtained in this manner in 16 ft. span railway trestles designed for Cooper's E-60 loading. There is not much liability to torsion or buckling with wood, as with steel I members with thin webs under heavy loads, especially when there is unsuspected corrosion after some years of service. In the case of timber roof or bridge joists, for spans over 13 ft., with conifer timbers which are comparatively weak in horizontal shear, a depth equal to as much as seven times the width has been employed with safety in the U. S. A. With such deep beams, diagonal bridging between joists at 8 ft. spacing is necessary to prevent lateral buckling. It has been recently discovered by the Forest Products Laboratory at Madison, Wisconsin, that the usual maximum

shear formula in a rectangular section $\frac{3}{2} \times \frac{\text{Reaction at support}}{\text{Area of section}}$ indicates greater stresses than are actually present, particularly with moving or concentrated loads near a support. In actual practice, due to seasoning checks in wood beams at the neutral plane, a "two-beam" effect comes into play, and the maximum shear is *not* at the end of a beam but at a distance of one to three times the height of the beam from the end.

Treated wood beams are employed in the U. S. A. for railway trestle bridges with a Cooper's loading of E.-72, an intensity of bridge loading that is unknown in India at present.

In the case of wood, it has been found by experiment, and has been accepted by the American Railway Engineering Association, that the strength of a cylindrical beam is the same as that of a square beam of the same cross-sectional area, instead of being only 85 per cent. of that strength as indicated by theoretical calculations and as is usual with every other kind of material known.

From the above, it would appear that while steel and wood have about equal safe strengths for the same weight, the latter is much cheaper (especially in the round) for a unit weight of material, *i.e.*, the weight corresponding to a unit value of strength as a beam or a column.

As regards concrete, it not only weighs considerably more for the same safe strength, but also costs much more.

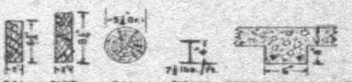
If steel is preferred to wood, it is usually for structures or structural members where the requisite strength cannot be obtained in a certain limited or economical volume. As regards durability, it may be mentioned that properly treated wood can give, in the case of most structures, the same life as properly and periodically painted steel, but with far smaller maintenance charges for periodical protective coatings during the life of the structure.

The attached diagrammatic statements show the relative cost of wood, steel, and concrete beams and columns designed for some commonly occurring load conditions. They speak for themselves.

If concrete is to be considered, there is practically only one argument in its favour,—*i.e.*, durability, which has been seriously subject to suspicion during recent years, when employed in wet locations and when not properly made or when exposed to frost. In marine work, it is now waterproofed and preserved with antiseptics. Even if it lasts for ever, it cannot compete with similiar treated wood structures provided the initial cost of the structure

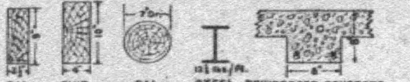
RELATIVE COST OF TIMBER, STEEL & REINFORCED CONCRETE BEAMS OF THE SAME SAFE STRENGTH.

DISTRIBUTED LOAD 2900 lbs. & SPAN 10 FEET.



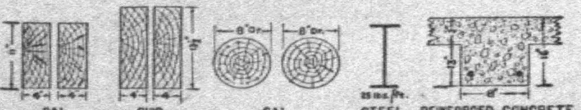
	SAL	CHIR	SAL	STEEL	REINFORCED CONCRETE (1:1½:3)
WT. OR VOL. (APPROX.)	0·94 C.Ft. (58 lbs.)	1·14 C.Ft. (46 lbs.)	1·5 C.Ft.	75 lbs.	2·5 C.Ft.
COST RATING	Rs. 4/- Per C.Ft.	Rs. 1/- Per C.Ft.	Rs. 3/- C.Ft.	Rs. 3½ Cwt.	Rs. 2/- Per C.Ft.
TOTAL COST (APPROX.)	Rs. 1·4	Rs. 1·4	Re. 0·8	Rs. 6·0	Rs. 5·0
COST RATIO	1	1	0·6	4·3	3·6

DISTRIBUTED LOAD 6500 lbs. & SPAN 12 FEET.



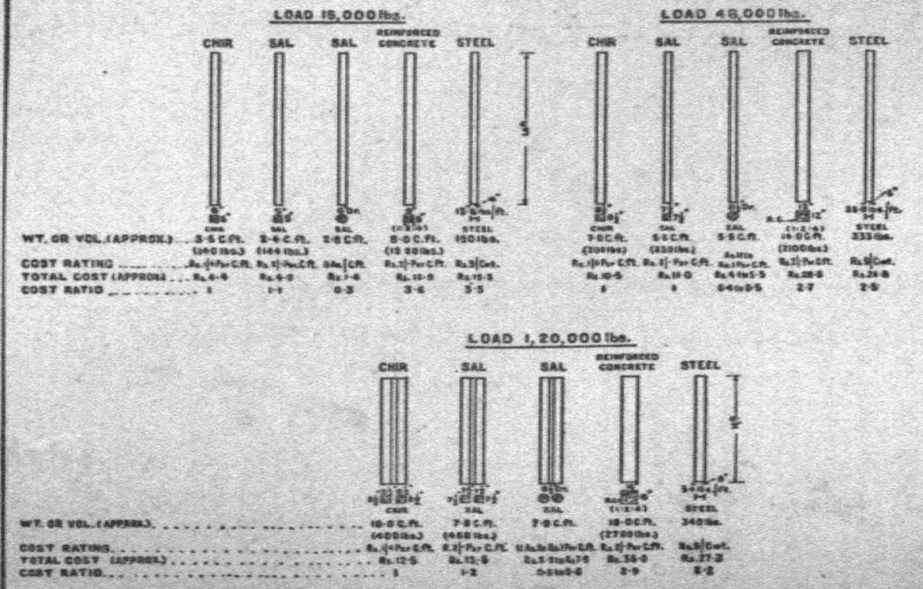
	SAL	CHIR	SAL	STEEL	REINFORCED CONCRETE (1:1½:3)
WT. OR VOL. (APPROX.)	2·5 C.Ft. (150 lbs.)	3·3 C.Ft. (132 lbs.)	3·2 C.Ft.	150 lbs.	5·3 C.Ft.
COST RATING	Rs. 2/2 Per C.Ft.	Rs. 1/- Per C.Ft.	Rs. 4/- C.Ft.	Rs. 9/- Cwt.	Rs. 2/- Per C.Ft.
TOTAL COST (APPROX.)	Rs. 4·4	Rs. 5·0	Rs. 2·0	Rs. 12·1	Rs. 10·6
COST RATIO	0·9	1	0·4	2·4	2·1

DISTRIBUTED LOAD 17000 lbs. & SPAN 15 FEET.



	SAL	CHIR	SAL	STEEL	REINFORCED CONCRETE (1:1½:3)
WT. OR VOL. (APPROX.)	9·2 C.Ft. (552 lbs.)	11·2 C.Ft. (448 lbs.)	10·6 C.Ft.	375 lbs.	13·3 C.Ft.
COST RATING	Rs. 2/4 Per C.Ft.	Rs. 2/0 Per C.Ft.	Rs. 12 As. to Rs. 1/- Per C.Ft.	Rs. 9/- Cwt.	Rs. 2/0 Per C.Ft.
TOTAL COST (APPROX.)	Rs. 20·7 (Max.)	Rs. 22·4 (Max.)	Rs. 8·0 to Rs. 10·6	Rs. 30·1	26·6
COST RATIO	0·9	1	0·4	1·3	1·2

RELATIVE COST OF TIMBER, STEEL & REINFORCED CONCRETE COLUMNS OF THE SAME SAFE STRENGTH



made with it is higher than 1½ times that of a similar structure of treated timber, the minimum life of which is 25 years. Since the unit of strength that can be obtained with concrete is much more expensive than that of wood, and as the cost of erection with concrete, involving considerable framing and false-work, is much higher than with wood, it will be seen that there is a good case for treated wood for most types of modern structures if unbiassed considerations of economy and ease of adaptation of structures to rapidly changing conditions prevail.

LIST OF PAMPHLETS TO BE ISSUED BY THE TIMBER DEVELOPMENT SECTION.

1. Wood's challenge to steel and concrete.
2. Relative economy of wood, steel and concrete structures.
3. Manufacture of small dimension stock as a rural industry.
4. The truth about fire hazard in timber structures.
5. Cheaper and better gable roofing with wood shingles.
6. Treated wood for earthquake resistant structures.
7. Treated wood poles for electric distribution and service.
8. Preservation of Indian woods with Ascu wood preservative.
9. Special factors affecting timber design.
10. Better and cheaper fencing.
11. How to build wooden earthquake and storm-proof houses.
12. Superiority of treated wood as modern structural material.
13. Relative cost of treated electric poles and overhead construction in India and abroad.
14. Specifications for treated wood poles for overhead electrical construction.
15. Treated timber bridges for Indian highways and railways.
16. The role of timber in hangar and aerodrome structures.
17. Comparison of cost of treating railway sleepers with Ascu and creosote.
18. Wood *versus* steel for framed buildings.
19. How to build fire-resistant timber structures.
20. Fire-proofing of wood.
21. Treated wood for roof trusses.
22. Treated wood for floors.
23. Treated wood for walls and ceilings.
24. Treated wood for pile foundations.
25. Treated wood for marine construction.
26. Wood *versus* steel for doors and windows.
27. Treated wood for tanks.
28. Cheap telephone construction.
29. Uses of forest thinnings.
30. Treated wood for agricultural construction.
31. Treated wood for mining construction.
32. Treated wood for irrigation and hydro-electric development.
33. Treated wood for ships and barges.
34. How to put up an inexpensive fire-place in a wooden house.

GIPD—M172 FRI &Coll DDun—2-12-36—3,000.